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Patentanmeldung Nr.      Patent application No.      Demande de brevet n°

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Der Präsident des Europäischen Patentamts;  
Im Auftrag

For the President of the European Patent Office

Le Président de l'Office européen des brevets  
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(Falls die Bezeichnung der Erfindung nicht angegeben ist, siehe Beschreibung.

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Therapeutical composition and use thereof

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**Therapeutical composition and use thereof**

This invention is related to a therapeutical composition, a method of its preparation, and corresponding methods of use, especially as a vaccine within a method of treatment for tumor associated disorders, Infectious disorders and transplantation associated disorders or treatment of allergic disorders.

The invention is related to the field of immunotherapy where in general pretreated dendritic cells are used as vaccines to stimulate or modulate an individual immune response.

Dendritic cells (DC) are considered to be the most important antigen presenting cells of the immune system. They sample antigen at the body's environmental interface and, under the appropriate conditions, mature and migrate to the lymphatic organs where they induce primary and enhance secondary immune responses. The conditions under which DC maturation is induced determine the outcome of the immune response. As an example, bacterial infection associated with inflammatory conditions leads to a T-helper (Th-) 1 response which is characterized by IFN $\gamma$  producing Th-cells. In contrast, parasite infections for example instruct DC to mount a Th-2 response with IL-4 producing Th-cells.

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DC are also described to induce under the appropriate conditions an unpolarized Th-0 response, or else they may anergize T-cells which results in tolerance. The mechanisms involved in this plasticity are affinity and duration of MHC II – TCR interaction, the expression pattern of costimulatory molecules, and the availability of cytokines (Kalinski P, Hilkens CM, Wierenga EA, Kapsenberg ML. *Immunol Today* 1999; 20(12):561-7).

The application of so called antigen-pulsed DC, i.e. DC loaded with antigens, is an extensively explored field (see for example the review of Yao, Platell, Hall, *Surg.* 72501 (2002)). The purpose is to immunize patients in need thereof against tumors (see e.g. Brossart et al. *Exp. Hematol.* 291247 (2001)), infectious agents or other pathogens (see review of Moll and Berberich, *J. Med. Microbiol.* 291323 (2001)). Great efforts are made with respect to the treatment of tumors that have become resistant to conventional therapeutical means. Especially in tumor therapy it is highly desirable to induce a sufficient antigen-specific Th-1 response.

A further application of pretreated DC, i.e. for the treatment of allergic diseases is discussed in Smits et al., *Int. Arch. Allergy Immunol.* 126:102 (2001). Allergic type I disorders are DC induced. They are Th-2-mediated immune reactions against harmless antigens. A therapeutic aim is to redirect this response towards a Th-1 reaction, which would abolish the allergic symptoms.

Dendritic cells can be prepared using different techniques. For human DC the preparation derived from blood monocytes is currently the most efficient. This method generates sufficient amounts of autologous DC. Such DC have been in vitro treated with several stimulatory compounds to mature and induce proliferation of lymphocytes. E. g. DC that were treated with MALP-2 or LPS induced a marked proliferation of autologous lymphocytes, but no significant polarization of lymphocytes into T-helper (Th-1) cells (Welgt, H., Mühlradt, P.F., Emmendorffer, A., Krug, N. *Braun, A., Immunobiol.* 2003 May 1; 207(3): 161-8). In general, the stimulation of mature DC through toll-like receptors alone may not suffice to induce a Th-1 immune response (Boonstra A, Asselin-Paturel C, Gilliet M, Crain C, Trinchieri G, Liu YJ, O'Garra A. *J Exp Med.* 2003 Jan 6;197(1):101-9.; Elsenbarth SC, Pigott DA, Huleatt JW, Visintin I, Herrick CA, Bottomly K. *J Exp Med.* 2002 Dec 16;196(12):1645-51.; Re F, Strominger JL. *J Biol Chem.* 2001 Oct 5;276(40):37692-9.).

Thus, there is still an urgent need to provoke or enhance Th-1-type immune responses *in vitro* and *in vivo*.

One object of this invention is to find a method to modulate an existing Th-2 response towards Th1 response or to provoke or enhance a Th-1 response and to influence the lymphocyte modulating potential of DC in the aforementioned direction. Since this is deemed to be an approach towards causative treatment of allergic disorders, it is a further object of the invention to provide a therapeutical composition for use in the treatment of allergic disorders, in tumor therapy and for the treatment of infectious diseases caused by viruses, bacteria, fungi or parasites. In autoimmune or transplantation-associated disorders, DC could improve organ function and survival. Another object of the invention is to provide a diagnostic tool to test the immune status of a patient. Here, the magnitude of an immuner- esponse after *in vitro* Th-1 stimulation of the cells of a patient can be quantified and com- pared to standard values.

The inventors now discovered that treatment of DC with a toll-like receptor 2 and/or toll-like receptor 6 agonist in combination with an IFNy receptor agonist stimulate DC to induce a Th-1 typical response in lymphocytes.

Therefore, according to one aspect of the present invention there is provided a method of treatment of a person in need thereof with dendritic cells pretreated in a manner as de- scribed below:

1. DC are generated *ex vivo* in cell culture, and stimulated with a toll-like receptor 2 and/or toll-like receptor 6 agonist in combination with an IFNy receptor agonist. The concentrations of the agonists can be adjusted by the skilled practitioner. Cell cul- ture can be carried out in the presence of antigen or antigen delivering or encoding vectors according to the practitioners need. After incubation (usually 7 days, with the last 48 h in presence of the stimuli), cells are either administered freshly into the patient via all available routes and/or are cryopreserved. They can be thawed and used when required according to the practitioners need.

2. DC are generated as mentioned above. Afterwards, DC are cocultured with leukocytes, preferably autologous lymphocytes. This mixture of cells will then be applied to the patient.
3. The cell mixture described in 2. will be separated after coculture, and each isolated cell population will be applied separately.

The DC cells used in connection with this invention can be taken from any suitable source. The source of DC includes progenitor derived DC, e.g., monocyte derived DC and stem cell derived DC, or DC from *in vivo* sources, e.g., myeloid DC, and lymphoid DC Techniques to obtain DC from human blood monocytes are described e.g. in T.G. Berger et al., J. Immunol. Methods 268: 131-140 (2002). The DC used should preferably be derived from autologous monocytes of a person or animal to be treated with the therapeutical composition according to the invention.

In a preferred embodiment the IFN $\gamma$  receptor agonist is human interferon gamma or a variant thereof, since most applications will be for human beings. In general the appropriate species-specific IFN $\gamma$  or variant should be used. Suitable interferon gamma receptor agonists are e.g. disclosed in Ioannovich et al. Intensive Care Med 1996 Oct;22 Suppl 4:S468-73. Musial et al. Allergy. 1995 Jun;50(6):520-3. Reumann. Pediatr Infect Dis J. 2001 Oct;20(10):995-6. Review. Aulitzky et al. Immunobiology. 1990 Jun;180(4-5):385-94. The term IFN $\gamma$  receptor agonist encompasses natural as well as synthetic molecules, including parts and derivates thereof as far as a sufficient activity to bind to the IFN $\gamma$  receptor is retained.

The toll-like receptor 2 and/or 6 agonist is preferably an agonist capable to signal via both toll-like receptors 2 and 6, like e.g. MALP-2 (see below); the agonist can also be a toll-like 2 or a toll-like 6 receptor agonist as far as a sufficient stimulation of DC can be achieved.

In a preferred embodiment the TLR 2/6 agonist is a bisacyloxypropyl-S-cystein derivative, or a lipopeptide derived from *Mycoplasma fermentans* or a corresponding synthetic lipopeptide capable to stimulate macrophages *in vitro* or *in vivo*, preferably Macrophage Activating Lipopeptide 2kDa (MALP-2) or biologically active derivates thereof. Suitable MALP variants are for example described in Mori M., Takeuchi O., Akira S., Simon M. M.,

Mühlradt P.F., Eur. J. Immunol. 2002, 32:3337-3347 and references cited therein. The toll-like receptor agonist molecules can be chemically modified, for example pegylated as disclosed for different proteins in EP 0 510 356 B1 and references cited therein.

For the preparation of the therapeutical composition according to the invention there is added at least one IFNy receptor agonist and at least one TLR 2 and/or TLR 6 agonist to a culture or solution of dendritic cells from any source whereupon this mixture is further used for the preparation of a therapeutical composition or as a therapeutical composition as such. The DC and receptor agonists as described above are cocultivated for at least 12 hours, preferably 48 hours. For the details reference is made to the examples.

The culture of the DC may further contain antigens, cells and/or substances, especially salts, nutrients, or other auxiliary agents and/or drugs.

According to a first embodiment of the invention the DC are washed after the first cultivation period and used for the further preparation of a therapeutical composition or as a therapeutical composition as such, preferably resuspended in saline, or any other physiological solution.

According to another embodiment the DC are then, after the first treatment with both agonists, i.e. after the first cultivation period, loaded with antigens according to established methods (e.g. Feuerstein et al. J. Immunol. Methods 245: 15-29 (2000)). These antigens have been identified to be important in connection with the disorders to be treated.

According to yet another embodiment of the invention lymphocytes, which are preferably autologous or allogenic lymphocytes acquired from the peripheral blood of donors, are added from the beginning or after the first cultivation period, whereafter the DC, the lymphocytes and optionally further ingredients are cocultivated for a time period up to several days, preferably for at least 12 or 48 hours, more preferred at least 3 days, and wherein the resulting culture is used for the further preparation of a therapeutical composition or as a therapeutical composition as such.

After these steps the lymphocytes can be separated from the culture, optionally washed and used for the further preparation of a therapeutical composition or as a therapeutical composition as such, preferably resuspended in, saline, or any physiological solution.

For medical use diluents, pharmaceutically acceptable carriers, auxiliary agents, drugs, and so on, can be added to the therapeutical composition obtained from said cells and/or mixtures to meet practical needs .

Thus, according to an important aspect of the invention there are provided new therapeutical compositions, which are obtainable by the methods disclosed above.

The therapeutical compositions according to this invention are useful as vaccines, for cell therapy and for the treatment of allergic disorders, malignancies, infectious disorders including viral, bacterial, fungal and parasite infections, autoimmune disorders and host-versus-graft or graft-versus-host reactions in transplantation. They contain DC and/or lymphocytes cocultivated with said DC, where the DC have acquired the property to drive a T helper cell type I response.

This invention further teaches the use of DC in combination with a least one IFNy receptor agonist and at least one TLR 2 and/or 6 agonist and the appropriate antigens or antigen delivering or encoding vectors according to the respective application for the manufacture of a medicament for the treatment of allergic disorders, cancer, e.g. melanoma, renal and prostate carcinoma or pancreas carcinoma, of viral infections, e.g. by HIV, Herpes and influenza, of bacterial infections, e.g. by Listeria, Salmonella, Mycobacteria, Chlamydia and Borrelia, of fungal infections, especially Candida, Aspergillus, Actinomyces. Further for the treatment of autoimmune disorders, e.g. Lupus erythematosus, type 1 diabetes and multiple sclerosis, and of transplantation associated diseases, especially graft-versus-host disease and host-versus-graft disease.

The medicament or the therapeutical composition of the invention may further contain pharmaceutically acceptable carriers or preservatives.

In general the invention encompasses the use of at least one IFNy receptor agonist in combination with at least one TLR 2 and/or TLR 6 agonist for the treatment of DC *in vivo* or *in vitro*.

For all embodiments of the invention described the therapeutical composition can be applied for example intradermally, subcutaneously, intravenously, inhalatively, intranasally, intranodally or in the case of cancer by injection into or near the tumor.

The invention also covers the use as a diagnostic tool to monitor the immune status of persons or animals. This is achieved by cocultivating DC which have been prestimulated with at least one IFNy receptor agonist and at least one TLR 2 and /or TLR 6 agonist with autologous or allogenic lymphocytes and measuring proliferation, release of molecules, cytotoxic activity and antibody formation. These parameters can be quantified and compared to standard values. A hyper- or hyporesponse to the stimuli indicates an deranged immune status.

## Experimental

An allergic reaction is characterized i.a. by an increased production of cytokines IL-4 and a decreased production of IFNy. To mimic the situation *in vitro* a useful model is to cocultivate allergen pulsed DC with autologous lymphocytes of patients suffering from an allergic disease.

For this purpose monocytes were derived from the blood of volunteers who reacted positively to *Dermatophagoides pteronyssinus* allergen DerP1 in a prick test. To one part of the DC only the allergen was added (group DerP1), another part was additionally treated with MALP-2 (group DerP1+MALP-2), another part with IFNy (group DerP1+IFN-g), and yet another part with both MALP-2 and IFNy (group DerP1+MALP-2+IFN-g). Further, there was an only solvent treated, unstimulated control (PBS). After cell harvest, all these groups were incubated with autologous lymphocytes (from the same volunteers).

The results are discussed below with reference to the figures and the examples.

#### Brief Description of the Drawings

**Fig. 1** Production of the cytokines IFN- $\gamma$  and IL-4 in the coculture of autologous lymphocytes with allergen-pulsed (DerP1) versus unpulsed (PBS) DC. DerP1 sensitive and healthy donors are opposed. The bracket indicates a significant difference ( $p \leq 0.05$ ) between the compared groups.

**Fig. 2** Flow cytometric analysis of DC harvested after 7 days of culture. The fluorescence profile of isotype-matched control, allergen-pulsed DC or allergen-pulsed and MALP-2 + IFN- $\gamma$  treated DC of one representative experiment is shown for each cell surface molecule.

**Fig. 3** Production of the cytokines IL-10 (a), IL12p70 (b) and TNF- $\alpha$  (c) after treatment of immature DC with PBS, DerP1, DerP1 + MALP-2, DerP1 + IFN- $\gamma$  or DerP1 + MALP-2 + IFN- $\gamma$ . The bracket indicates a significant difference ( $p \leq 0.05$ ) between the compared groups.

**Fig. 4** Proliferative response measured by  $^3$ H-Thymidine incorporation after coculture of DC pretreated with PBS, DerP1, DerP1 + MALP-2, DerP1 + IFN- $\gamma$  or DerP1 + MALP-2 + IFN- $\gamma$  and autologous lymphocytes. Each curve represents the mean 6 individual experiments of titrated DC cocultured with a constant number of lymphocytes. The last point (lymphocytes) shows lymphocytes without DC.

**Fig. 5** Ratio of IFN- $\gamma$  production to IL-4 production after coculture of DC pretreated with PBS, DerP1, DerP1 + MALP-2, DerP1 + IFN- $\gamma$  or DerP1 + MALP-2 + IFN- $\gamma$  and autologous lymphocytes.

**Table legends**

**Tab. 1** Flow cytometric analysis of DC after treatment with PBS, DerP1, DerP1 + MALP-2, DerP1 + IFN- $\gamma$  or DerP1 + MALP-2 + IFN- $\gamma$  for 48 hours. The mean  $\pm$  SEM of the median fluorescence intensities of 6 individual experiments is shown.

**Tab. 2** Production of the cytokines IFN- $\gamma$  and IL-4 in the coculture of DC pretreated with PBS, DerP1, DerP1 + MALP-2, DerP1 + IFN- $\gamma$  or DerP1 + MALP-2 + IFN- $\gamma$  and autologous lymphocytes. The mean  $\pm$  SEM of 6 individual experiments is shown.

## Material and Methods

### **Patients**

Blood was collected from, if not otherwise mentioned, 6 allergic patients with a positive skin-prick test response to affinity purified DerP1 (ALK Scherax, Hamburg, Germany), the major allergen of the house-dust mite *Dermatophagoides pteronyssinus*. A positive response was defined by a wheal of 3 mm or greater. 0,9% NaCl solution served as negative control, histamine as positive control. Blood of 6 donors with a negative test was used in control experiments. All donors gave their informed consent. The study was approved by the ethics committee of the Hannover Medical School.

### **Generation of DC**

Monocyte derived DC were generated as previously described (Weigt et al. Immunobiol. 207, 223-233 (2003). Briefly, blood was centrifuged to remove platelets, diluted and layered over Ficoll-Paque (Amersham Pharmacia, Uppsala, Sweden). After density gradient centrifugation, PBMC were collected, and monocytes were enriched using the MACS system and anti-CD 14 beads (Miltenyi Biotec, Bergisch Gladbach, Germany). The CD14 positive fraction (monocytes) was cultured in the serum-free medium X-VIVO 15 supplemented with 100 U/ml penicillin and 100 ng/ml streptomycin (all BioWhittaker, Verviers, Belgium). The CD14 negative fraction containing the lymphocytes was cryopreserved in 90% FCS (GIBCO, Eggenstein-Leopoldshafen, Germany) and 10% DMSO (SIGMA, Taufkirchen, Germany). On day 1 and day 5 after isolation, 800 U/ml of recombinant GM-CSF and 500 U/ml of recombinant IL-4 (Strathmann Biotec, Hamburg, Germany) were added to the monocyte culture to induce DC. On day 5, cells endocytose FITC-labeled Dextran and express the Toll-like receptors -2 and -6, which are associated with MALP-2 signaling.

### **Stimulation of DC**

On day 5 of the culture, DC were pulsed with affinity purified house dust mite allergen adjusted to a concentration of 100 ng/ml of DerP1 or with PBS as control. DC were further treated with 100 pg/ml of MALP-2 synthesized and purified as described (Morr et al. Eur J Immunol 2002; 32(12):3337-47), 5000 U/ml of IFN- $\gamma$  (Strathmann Biotec), with both substances at the same concentrations or with PBS (control). The respective optimal concentrations were experimentally determined using the highest expression of stimulatory cell surface molecules as read-out system. The substances were incubated on the cells for 48 hours.

### **Flow cytometric analysis of DC**

For immunophenotyping, an aliquot of DC was harvested after 7 days of culture and washed in PBS supplemented with 0.5 % FCS and 10 mM NaN<sub>3</sub> (SIGMA, Taufkirchen, Germany). After 30-minute-incubation at 4°C with one of the following combination of labeled murine mAbs (isotype control FITC / isotype control PE, anti-CD83 FITC, anti-CD86 FITC / anti-CD40 PE, anti-CD 80 FITC / anti-HLA-DR PE, anti-CD1a FITC / anti-CD14 PE (all BD Biosciences, Heidelberg, Germany)) cells were washed and analysed on a EPICS XL-MCL (Beckmann Coulter, Krefeld, Germany) flow cytometer. Data were processed with the Expo 32 cytometer software (Beckmann Coulter). The expression of the cell surface molecules was shown in 1 parameter Histograms (Fig. 2) or evaluated using the median of fluorescence intensity (MFI) after subtraction of the values of the isotype control (Tab. 1).

### **Determination of cytokines**

Cytokine concentrations were determined in DC culture supernatant collected on day 7 (TNF- $\alpha$ , IL-10, IL-12) and in the supernatant of the coculture of DC and autologous lymphocytes collected on day 10 (IFN- $\gamma$ , IL-4). Duo-Set ELISA kits for the detection of IL-12p70, IL-10, TNF, IFN- $\gamma$ , IL-4 and IL-5 were purchased (R&D Systems, Wiesbaden, Germany) and performed according to the manufacturers instructions.

### **Coculture of DC with autologous lymphocytes**

A portion of DC was used for coculture experiments with autologous lymphocytes from day 7 to day 13. To remove free stimulants, DC were harvested and washed twice. The cells were titrated in fresh medium in fresh round-bottom microtiterplates.  $1 \times 10^5$  vital cryopreserved autologous lymphocytes were added at ratios of DC to lymphocytes from 1:3 to 1:2187 in a final volume of 200  $\mu$ l in serum-free XIVO-15. No further stimulants were given.

### **Proliferation assay**

The coculture was pulsed with 5  $\mu$ Ci/ml  $^3$ H-thymidine (Amersham Buchler, Braunschweig, Germany) on day 12. After 18 hours, the cells were harvested on filtermats (Canberra-Packard, Dreieich, Germany). After drying, 20  $\mu$ l of liquid scintillator (Canberra-Packard) were added and the plates were sealed. Counts per minute were determined on a Top-count Microplate Scintillation Counter (Canberra-Packard).

### **Blocking of IL-12p70 in the coculture**

Directly after preparing the coculture (day 7), an IL-12p70 blocking antibody (R&D Systems) was added in a final concentration of 3  $\mu$ g/ml. Controls using an unspecific isotype

control antibody (R&D Systems) were included. The same concentration of antibodies was again given after 3 days (day 10). IL-12p70 blocking was performed in the coculture of DC pretreated with DerP1, MALP-2 and IFN- $\gamma$  with autologous lymphocytes of 3 individual experiments.

### **Statistical analysis**

Data are presented as the mean of all experiments  $\pm$  SEM. The paired student t-test was applied for statistical analysis. From respective controls, differences of  $p \leq 0.05$  were considered significant.

## **Results**

### **DC pulsed with DerP1 induce a Th2-skewed immuneresponse in autologous lymphocytes of allergics**

To build up a test system to evaluate the potential of DC to modulate allergic immunoreaction, DC of house dust mite allergic donors and of healthy control donors were pulsed with DerP1, the major allergen of the house dust mite *Dermatophagoides pteronyssinus*. Controls remained unpulsed. After a 2 day incubation period, DC were harvested and coincubated with autologous lymphocytes. Cell culture supernatant was collected on day 3 of the coculture and analyzed for the concentrations of IFN- $\gamma$  and IL-4 by ELISA (Fig. 1). Using unpulsed DC, IFN- $\gamma$  concentrations of allergics and healthy donors were comparable (7,7 pg/ml  $\pm$  3,7 (allergics) vs. 11,6 pg/ml  $\pm$  2,5 (healthy)). In allergics, pretreatment of DC with DerP1 resulted in a significant reduction of IFN- $\gamma$  (3,6 pg/ml  $\pm$  5,1), while no change was observed in non-allergics (8,7 pg/ml  $\pm$  6,6). Consequently, IL-4 concentration was below the detection limit of the ELISA in healthy donors, whether DC have been pulsed or not. In

Contrast, DerP1 pretreated DC induced a significant upregulation of IL-4 (13,6 pg/ml  $\pm$  7,3) in allergics compared to unpulsed DC (9,0 pg/ml  $\pm$  5,8).

**MALP-2 and IFN- $\gamma$  synergistically increase surface molecules associated with maturation of DC**

To test the influence of DerP1, MALP-2 and IFN- $\gamma$  on DC maturation, immature cells (day 5) of allergics were flow cytometrically analyzed after 48h of incubation with the substances. The surface expressions of CD80, CD86, CD 40, HLA-DR, CD83, CD14 and CD1a were determined. Pulsing of DC with DerP1 had no effect on the expression of the surface molecules compared to untreated DC. MALP-2 significantly upregulated CD 40, CD 80, CD 83 and CD86, while IFN- $\gamma$  upregulated only HLA-DR. Using both substances to stimulate DC, a strong synergistic amplification of CD 40, CD 80, CD 83 and CD86 and HLA-DR was observed. Expression of CD 1a as well as the low-level expression of CD 14 was not affected (Fig. 2). A table giving the mean fluorescence intensities of all experiments is shown (Tab. 1).

**Induction of IL-12p70 by combined MALP-2 and IFN- $\gamma$  is associated with a reduction of IL-10**

To further analyze the maturing effect of MALP-2 and IFN- $\gamma$  treatment, the production of TNF, IL-10 and IL-12p70 were analysed in the cell culture supernatants by ELISA after 7 days of cell culture. Stimulation with DerP1 or with IFN- $\gamma$  did not influence the production of IL-10 and IL-12 compared to untreated DC. MALP-2 only induced IL-10 and had no effect on IL-12. A striking difference was observed when stimulating with MALP-2 and IFN- $\gamma$ : IL-12 was massively increased, which was associated with the complete reduction of IL-10

to basal levels. (Fig. 3 a,b). TNF was produced at low levels in the unstimulated control group and in the DerP1 pulsed group. MALP-2 and IFN- $\gamma$  induced a comparable moderate release, while both stimuli together more than doubled the concentration of TNF compared to the single substances (Fig. 3 c).

#### **MALP-2 and IFN- $\gamma$ synergistically increase allergen-associated proliferation**

To assess the functional effects of MALP-2 and IFN- $\gamma$  treatment, DC were cocultured after their harvest on day 7 with autologous lymphocytes. Therefore, unbound stimulants were removed by washing, DC were seeded at various cell numbers in fresh medium and new cell culture plates, and a constant number of the cryopreserved autologous lymphocytes was added. To determine proliferation, the coculture was pulsed with  $^3$ H-thymidine on day 12 for further 18 hours. In allergics, pulsing of DC with DerP1 always resulted in a higher proliferative response in all preparations which was not observed in healthy control donors (data not shown). This demonstrates the induction of a secondary immuneresponse in the test system. Using DC of allergics, allergen pulsing exerted only a very weak effect on lymphocyte proliferation. Pretreatment of pulsed DC with IFN- $\gamma$  increased proliferation, which was exceeded by MALP-2. The strongest response however could be measured by stimulating DC with allergen and both substances (Fig. 4).

#### **Combined MALP-2 and IFN- $\gamma$ pretreatment shifts the Th2-skewed immune response to Th1**

To analyze the effect of MALP-2 and IFN- $\gamma$  pretreatment on the allergen-dependent Th2 skewed immune response using cells of allergic donors, the cytokines IFN- $\gamma$  and IL-4 were measured in the supernatant of the coculture. For this experiment, an optimal titration ratio of 1:3 (DC:lymphocytes) was used. As here described, DerP1-pulsing induced an in-

crease in IL-4 and a reduction of IFN- $\gamma$ . Additional MALP-2 pretreatment reduced IL-4 to control levels and lowered IFN- $\gamma$  less compared to allergen pulsed DC, resulting in minor skewing. IFN- $\gamma$  pretreatment had little effect on IL-4, but heightened lymphocyte IFN- $\gamma$  production. This effect was strongly exceeded by stimulating DC with MALP-2 and IFN- $\gamma$ : While IL-4 was not even doubled, IFN- $\gamma$  production increased more than 50-fold compared to only allergen pulsed DC, showing the characteristics of a Th1 immuneresponse.

## Discussion

DC have the potential of inducing different responses in lymphocytes. Depending on DC treatment, lymphocytes get activated or anergic, polarized according to the Th1/2 model or become Th0. This potential is termed plasticity of DC (Huang et al. *Science* 2001; 294(5543):870-5). In this study, it was shown that only DerP1-pulsed, otherwise immature DC of house dust mite allergics induce an autologous Th2- response ( $\downarrow$  IFN- $\gamma$ ,  $\uparrow$  IL-4), but that equally treated DC of non-allergics have no effect on lymphocytes ( $\rightarrow$  IFN- $\gamma$ ,  $\rightarrow$  IL-4). This model was used to analyze the effect of DC stimulation with MALP-2 and IFN- $\gamma$  on lymphocyte activation and polarization with the aim to shift the existing Th2- towards a Th1-response.

MALP-2 stimulation is known to induce maturation of DC. It upregulates costimulatory cell surface molecules and induces IL-10 secretion, while IL-12p70, a cytokine pivotal for inducing Th1 responses, was not produced. When cocultured with lymphocytes, MALP-2 treatment of DC leads to an enhanced lymphocyte proliferation, but does not influence the Th-polarization compared to unstimulated control-DC (Weigt et al. *Immunobiol.* 207, 1-11 (2003)).

IFNg, in contrast, is described to reduce immunstimulatory capacity of DC by downregulating costimulatory molecules (Rongcun et al. Cytokine 1998 Oct;10(10):747-55).

Because of the findings for the individual substances, the astonishing upregulation of costimulatory molecules, of lymphocyte proliferation and the induction of Th1-responses of DC pretreated with MALP-2 together with IFN-g was not deducable from the pattern induced by either one of the stimuli.

The massive induction of IL-12 proved to be of high importance for the effects seen in lymphocytes when cocultivating with respectively treated DC: the transfer of the allergen-dependent Th2 response to Th1 was reducible by blocking this cytokine with appropriate antibodies.

We surprisingly found that stimulation of DC with MALP-2 and IFNy substantially improve DC for therapeutic use. As pointed out, the Th1-shifting effect of an established Th2 response implies a causative cure for allergic disease (Huang et al. J Immunol 2001; 166(1):207-17). The practitioner has to adapt the regimen in accordance with the requirements of the specific case.

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**Patent- und Rechtsanwaltssozietät**  
**Gesellschaft bürgerlichen Rechts**

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**Claims:**

1. A Method for the preparation of a therapeutical composition, characterized in that dendritic cells (DC) from any source are cultured in the presence of at least one IFNy receptor agonist and at least one TLR (toll like receptor) 2 and/or TLR 6 agonist, whereupon this mixture is further used for the preparation of a therapeutical composition or as a therapeutical composition as such.
2. The method of claim 1, wherein the source of DC includes progenitor derived DC, e.g. monocyte derived DC and stem cell derived DC, or *in vivo* existent DC, e.g. myeloid and lymphoid DC, and wherein the DC are preferably derived from autologous monocytes of a person or animal to be treated with the therapeutical composition.
3. The method of claim 1 or 2, wherein the IFNy receptor agonist is the appropriate species-specific interferon gamma or a variant thereof.
4. The method according to one of claims 1 to 3, wherein the TLR 2/6 agonist is a bisacyloxypropyl-S-cystein derivative, e.g. a lipopeptide derived from *Mycoplasma fermentans* or a corresponding synthetic lipopeptide capable to stimulate macro-

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phages *in vitro* or *in vivo*, preferably Marophage Activating Lipopeptide 2kDa (MALP-2) or biologically active derivatives thereof.

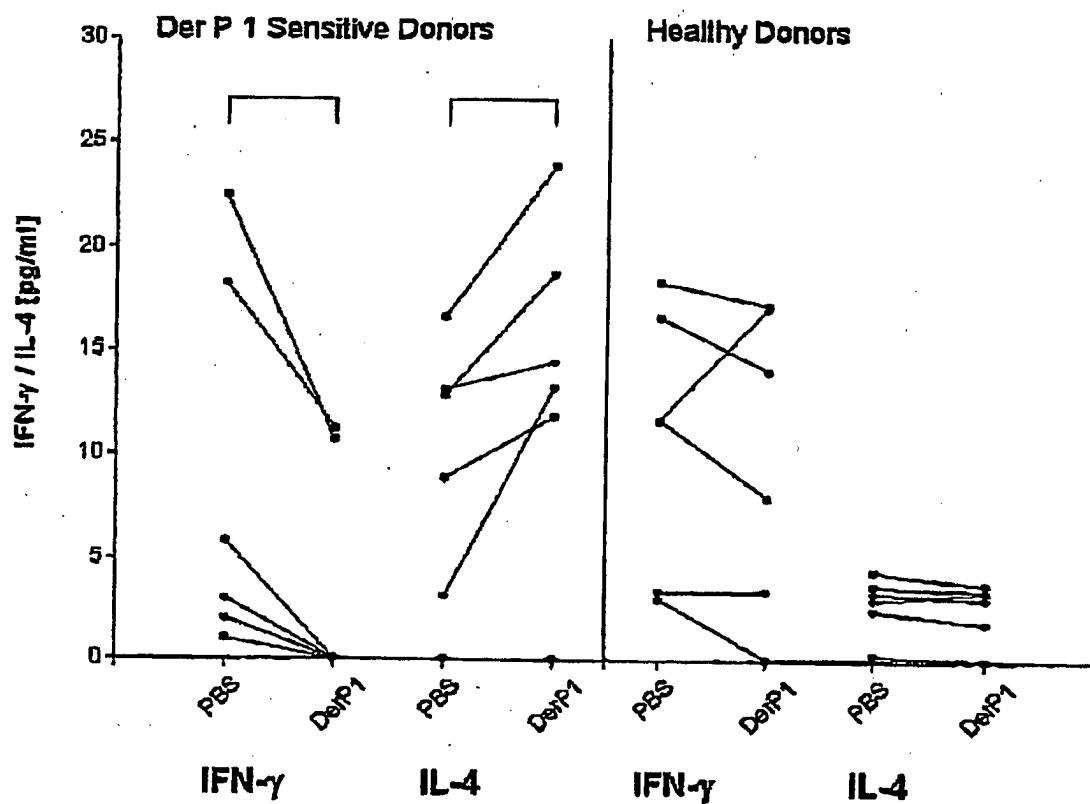
5. The method according to one of claims 1 to 4, wherein the treated DC are finally washed and preferably resuspended in water, saline or physiological medium.
6. The method according to one of claims 1 to 5, wherein the DC are loaded with antigens according to established methods.
7. The method according to one of claims 1 to 6, wherein autologous or allogeneic lymphocytes acquired from the peripheral blood of donors are added, whereafter the DC and the lymphocytes and optionally further ingredients are cocultivated for a time period of up to several days, preferably at least 24 hours, more preferred at least 3 days, and wherein the resulting culture is used for the further preparation of a therapeutical composition or as a therapeutical composition as such.
8. The method according to claim 7, wherein the lymphocytes are separated from the culture, optionally washed and used for the further preparation of a therapeutical composition or as a therapeutical composition as such, preferably resuspended in water, saline, or medium.
9. A therapeutical composition containing DC and/or lymphocytes cocultivated with said DC, where the DC have acquired the property to drive a T helper cell type I response.
10. A therapeutical composition according to claim 9 obtainable by the method according to one of claims 1 to 8.
11. A use of the therapeutical composition according to claim 9 or 10 as a vaccine for the treatment of malignancies, allergic disorders, infectious disorders including viral, bacterial, fungal and parasite infections, autoimmune disorders and

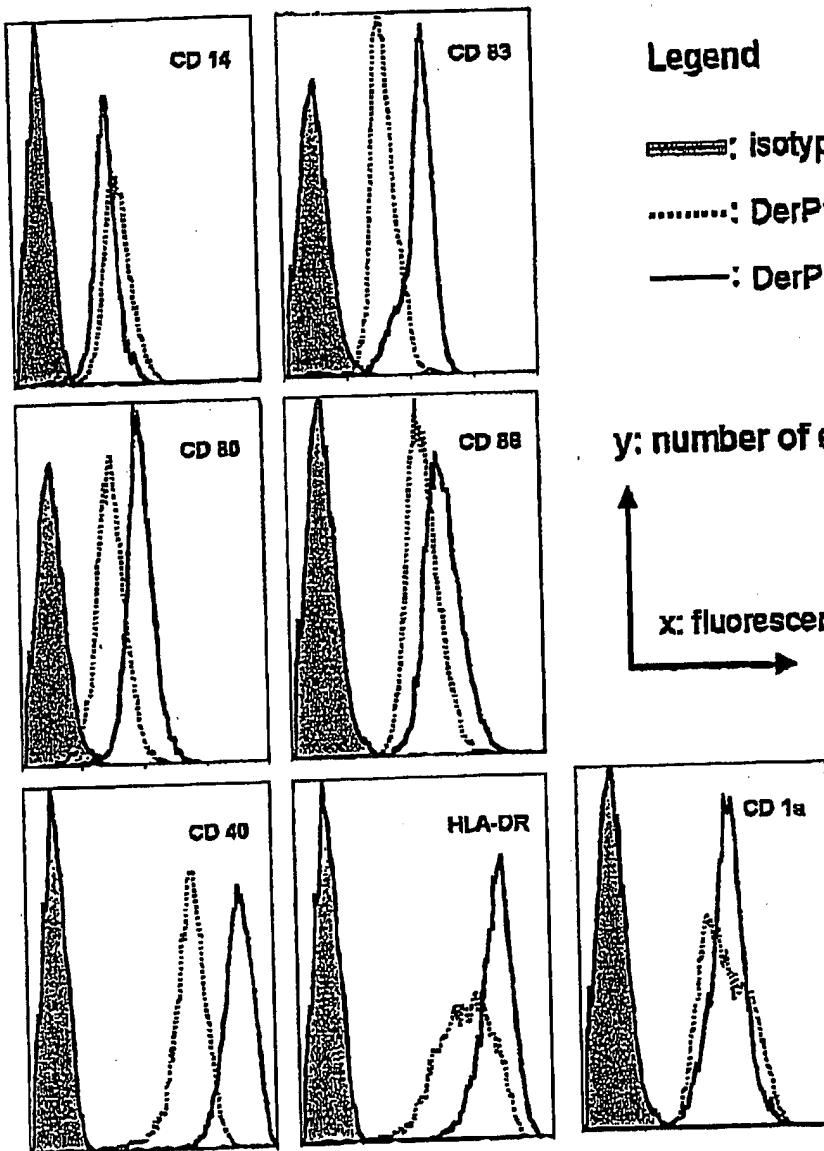
host-versus-graft or graft-versus-host reactions in transplantation.

12. The use of DC treated *in vitro* with at least one IFNy receptor agonist in combination with at least one TLR 2 and/or TLR 6 agonist for the manufacture of a therapeutical composition for medical use, especially for the treatment of malignancies, allergic disorders, infectious disorders including viral, bacterial, fungal and parasite infections, autoimmune disorders and host-versus-graft or graft-versus-host reactions in transplantation.
13. The use of lymphocytes cocultivated with DC treated with at least one IFNy receptor agonist in combination with at least one TLR 2 and/or TLR 6 agonist for the manufacture of a therapeutical composition for medical use, especially for the treatment of malignancies, allergic disorders, infectious disorders including viral, bacterial, fungal and parasite infections, autoimmune disorders and host-versus-graft or graft-versus-host reactions in transplantation.
14. The use according to claim 12 or 13, where the DC have been treated with a method according to one of claims 1 to 8.
15. A diagnostic method to monitor the immune status of persons or animals characterized in that DC which have been prestimulated with at least one IFNy receptor agonist and at least one TLR 2 and /or TLR 6 agonist are cocultivated with autologous or allogenic lymphocytes, whereafter proliferation, release of molecules, cytotoxic activity and/or antibody formation are measured, and the data is evaluated.

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Fig. 1



**Fig. 2****Legend**

- : isotype control
- : DerP1
- : DerP1+MALP-2+IFN- $\gamma$

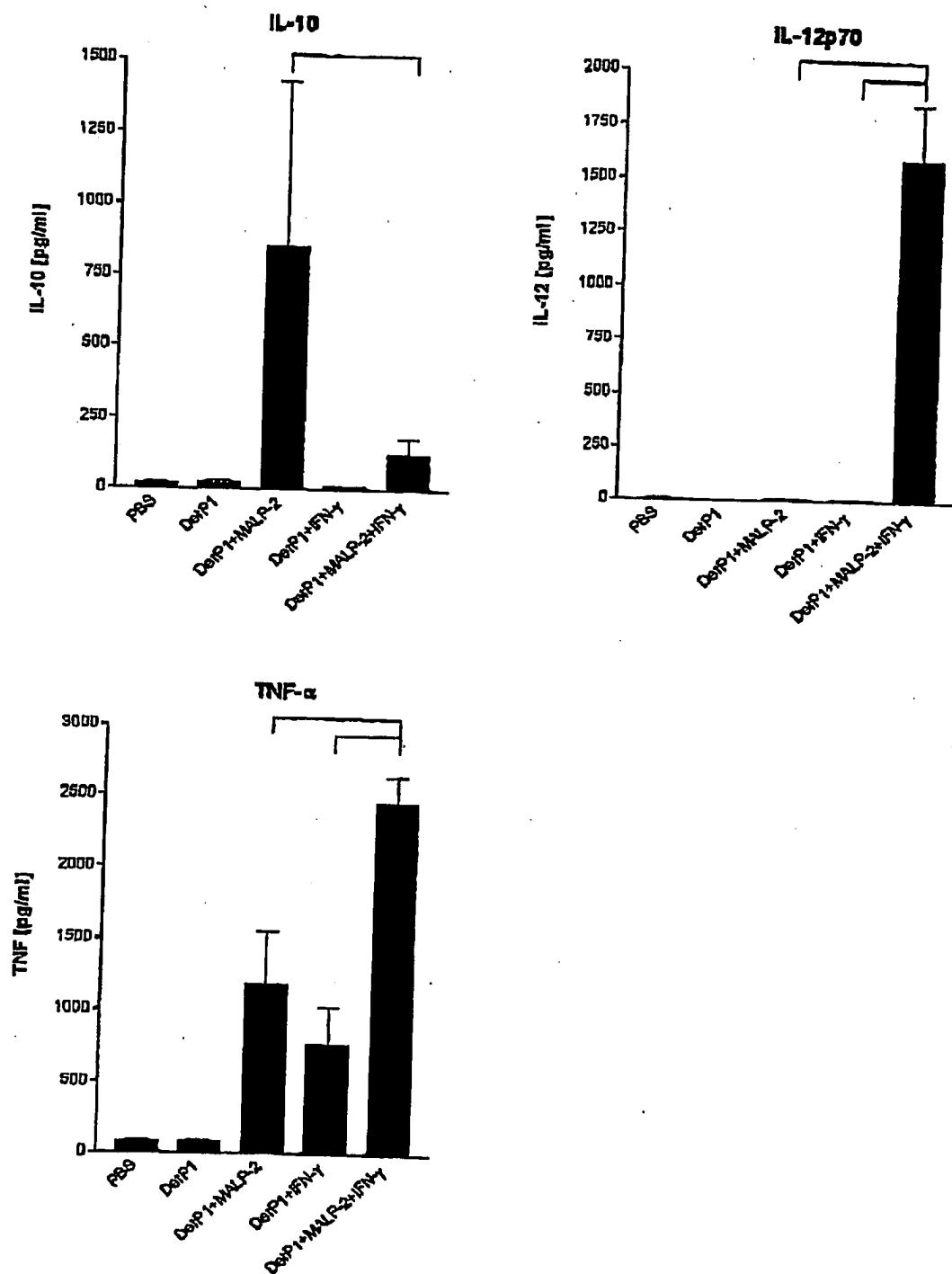
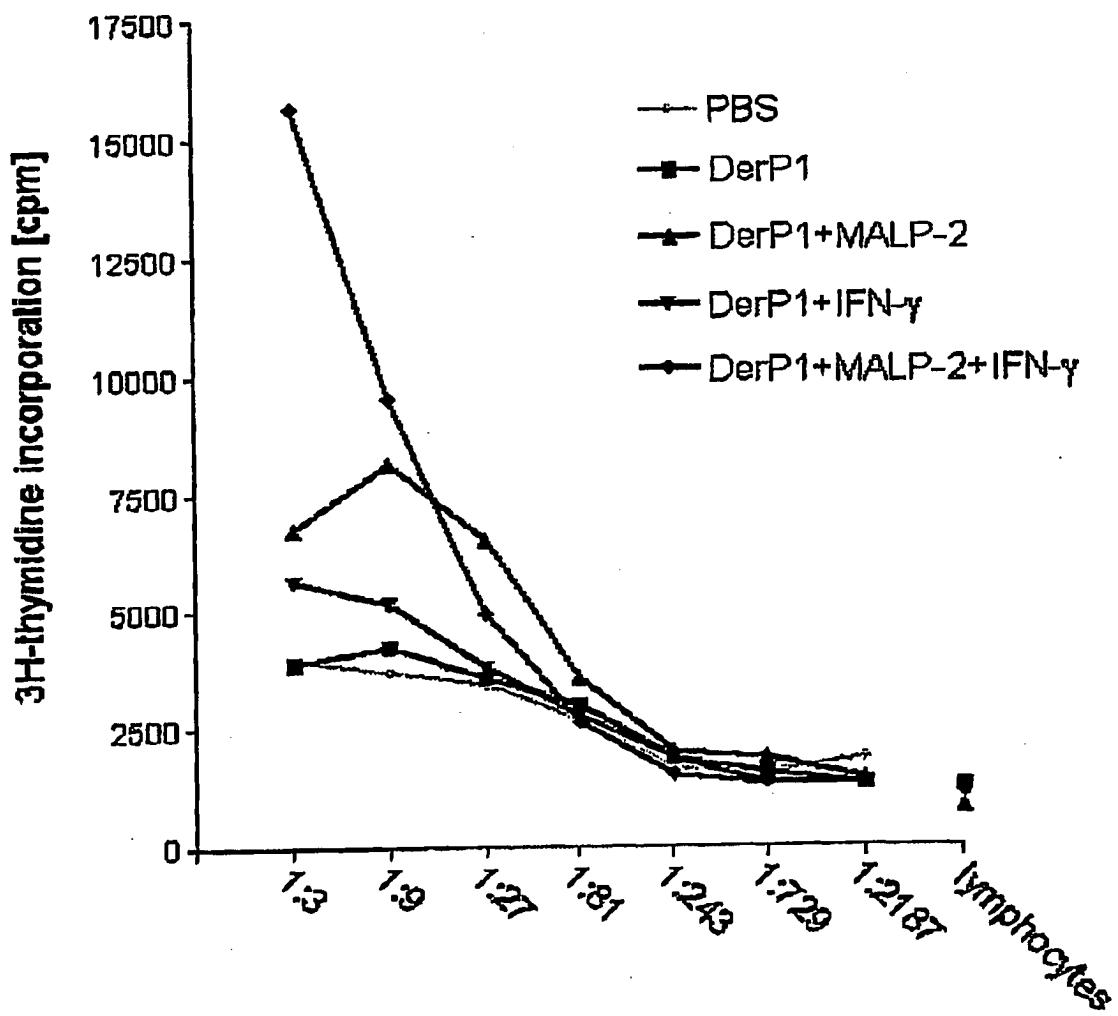
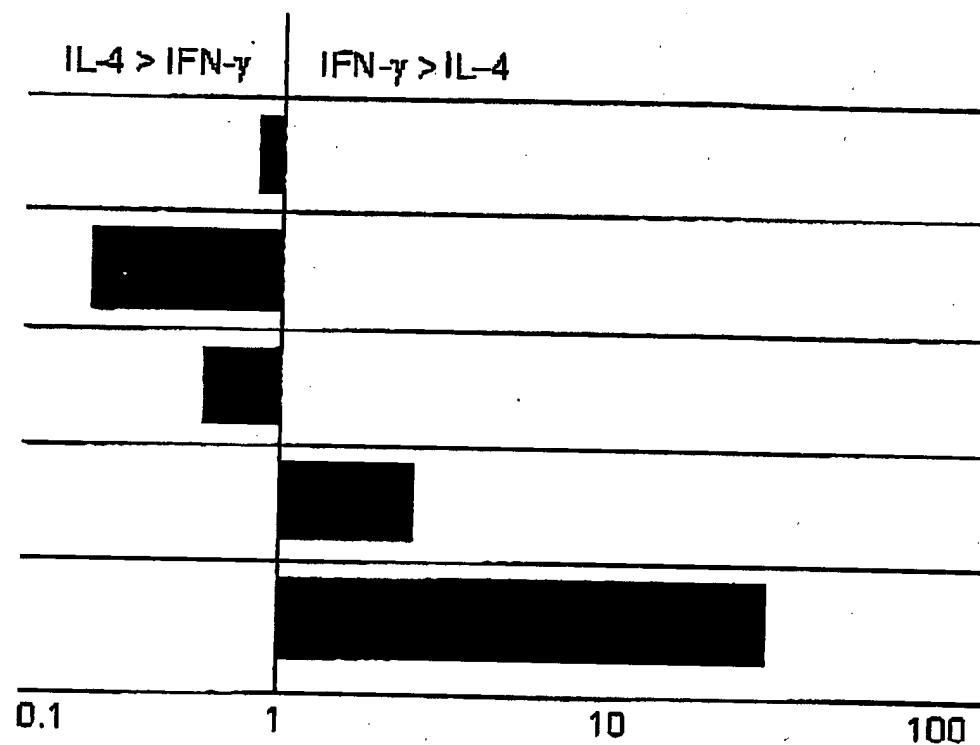
**Fig. 3**

Fig. 4



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Fig. 5

Ratio IFN- $\gamma$  / IL-4

**Table 1**

	CD 14	CD 83	CD 80	CD 86
PBS	18,4 +/- 9,7	55,6 +/- 8,3	44,4 +/- 17,9	173,1 +/- 29,1
DerP1	17,6 +/- 9,8	47,3 +/- 9	47,2 +/- 18,9	159,8 +/- 29,3
DerP1+MALP-2	32,2 +/- 12,6	72,4 +/- 8,8	103,7 +/- 31,2	260,2 +/- 53,8
DerP1+IFN- $\gamma$	16,4 +/- 10,1	38,6 +/- 6,2	69,3 +/- 17,2	123,9 +/- 25,7
DerP1+MALP-2+IFN- $\gamma$	17 +/- 6,8	90,7 +/- 14,6	248,5 +/- 94,3	358,9 +/- 63,7
	CD 40	HLA-DR	CD1a	
PBS	670,6 +/- 153,6	390,9 +/- 109,9	207,8 +/- 68,1	
DerP1	733 +/- 160,5	426,9 +/- 131,9	265,2 +/- 106,8	
DerP1+MALP-2	1389,6 +/- 269,9	746,1 +/- 295	291,2 +/- 109,3	
DerP1+IFN- $\gamma$	1769,4 +/- 519,9	669,1 +/- 204,2	199 +/- 69	
DerP1+MALP-2+IFN- $\gamma$	2673,9 +/- 717,5	1253,8 +/- 417,6	199,9 +/- 69,9	

**Table 2**

	IL-4	IFN- $\gamma$
PBS	9 +/- 5,8	8,7 +/- 3,8
DerP1	13,6 +/- 7,3	3,6 +/- 2,1
DerP1+MALP-2	9,6 +/- 6,4	5,7 +/- 3,9
DerP1+IFN- $\gamma$	11,8 +/- 7	29,6 +/- 9,3
DerP1+MALP-2+IFN- $\gamma$	17,1 +/- 8,6	505,5 +/- 176,7